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Modelling the Impacts of Land Use Change for the Tone Catchment with a Physically Distributed Model

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Introduction

- A physically fully distributed model has been built with MIKE SHE/11 and used to evaluate catchment response, subject to a variety of land use management practices.
- Scenarios were designed considering agricultural practices in order to explore the potential impact of land use changes on river flow and the effectiveness of flood storage on flood risk.
- The impact has been explored from the upper to down stream of the Tone Catchment.

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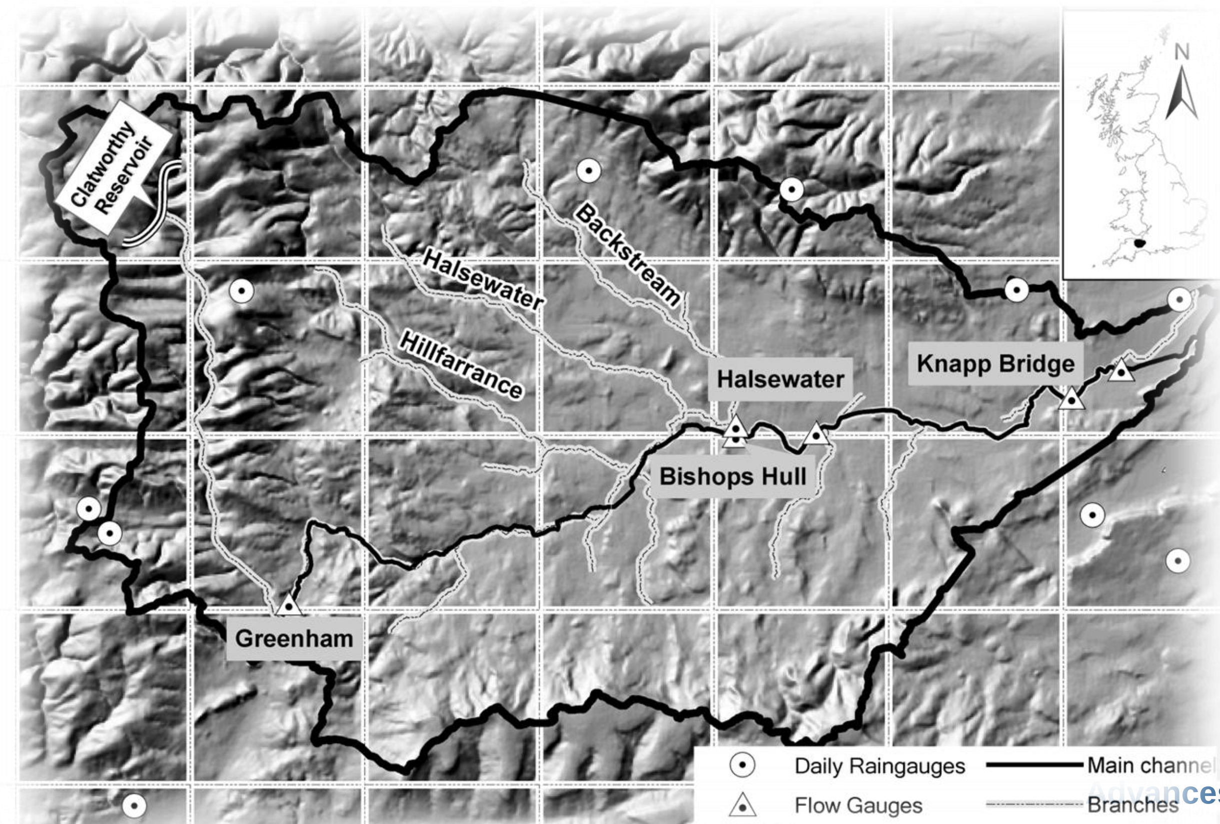
Study Site: River Tone

- Located in the South West of the United Kingdom(414 km^2)
- Intensive Agricultural Practices
- High Siltation/Sedimentation
- Long history of Flood Defence since Roman times




Source of the Tone


Maize Farm


Halsewater

Floods in the Tone

- **Flood records date back to 1607.**
- **Severe floods:**

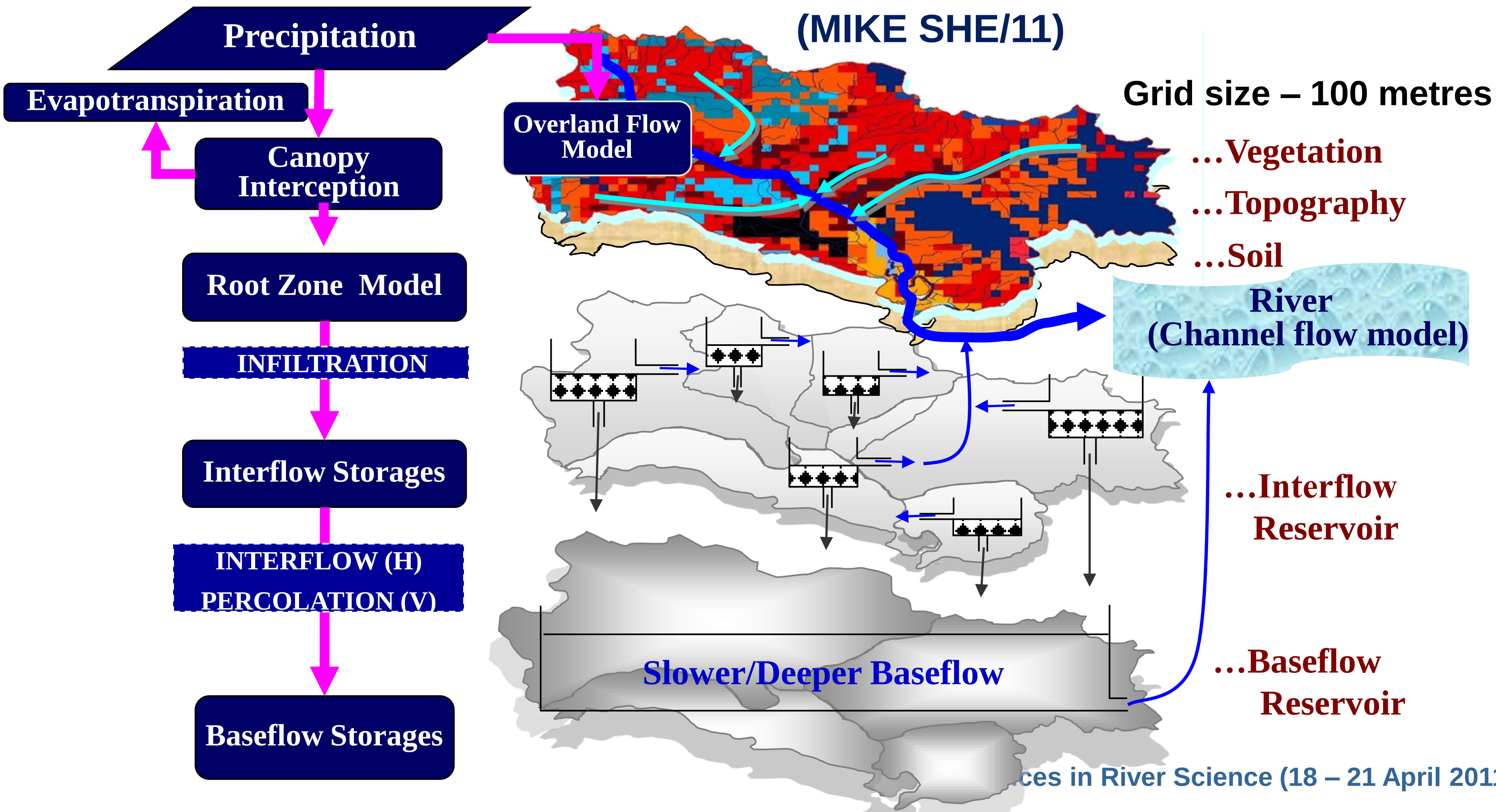
Bridgwater (1957, 1963 and 1974) & Taunton (1960, 1999 & 2000)

Floods & Soil Fertility

Winter Dormant And Bare Ground + Rain On Loamy & Silt Soil → Soil Productivity?

Physically Distributed Model

Water Movement Procedures | **Vertical Data Layers**



Parameter Optimisation

Shuffled Complex Evolution (SCE)

- Sampling with Monte Carlo methods
- Customised using the parameters chosen for optimisation including
  - Local Sensitivity Analysis (pre-procedure)
  - Random Initialisation of samples for parameter sets
  - Partitioning complexes using seed numbers
  - Evolution of complexes
  - Complex shuffling

Initial Values

- Reflected the local scale heterogeneity of surface height, surface roughness, soil and vegetation type.
- Interpreted as averages over the fundamental model units

Parameters

Model Process	Description
Unsaturated zone	Main soil classes - HOST class: 2, 3, 9, 11, 17, 18, 21, 23, 25. • Water content at saturation (WCS, *p4*) • Water content at field capacity (FC, *p5*) • Water content at wilting point (WP, *p6*) • Saturated hydraulic conductivity (HC, *p7*) Initial values are set with average value for each class.
Saturated zone	Two layers; Parameters for ***interflow reservoirs (Shallow Groundwater)***: • Interflow time – flow to the next reservoir (lateral movement) (*p1*) • Percolation time – reach to the baseflow reservoir (*p2*) • Specific yield (*p3*) Parameters for ***baseflow reservoirs***: • Fraction of base flow to the river (*p8*) • Specific yield (*p9*) • Fraction of unaccounted water of the received percolation flow (*p11*) Initial values were gained through the trial-and-error phase.

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Calibration Results

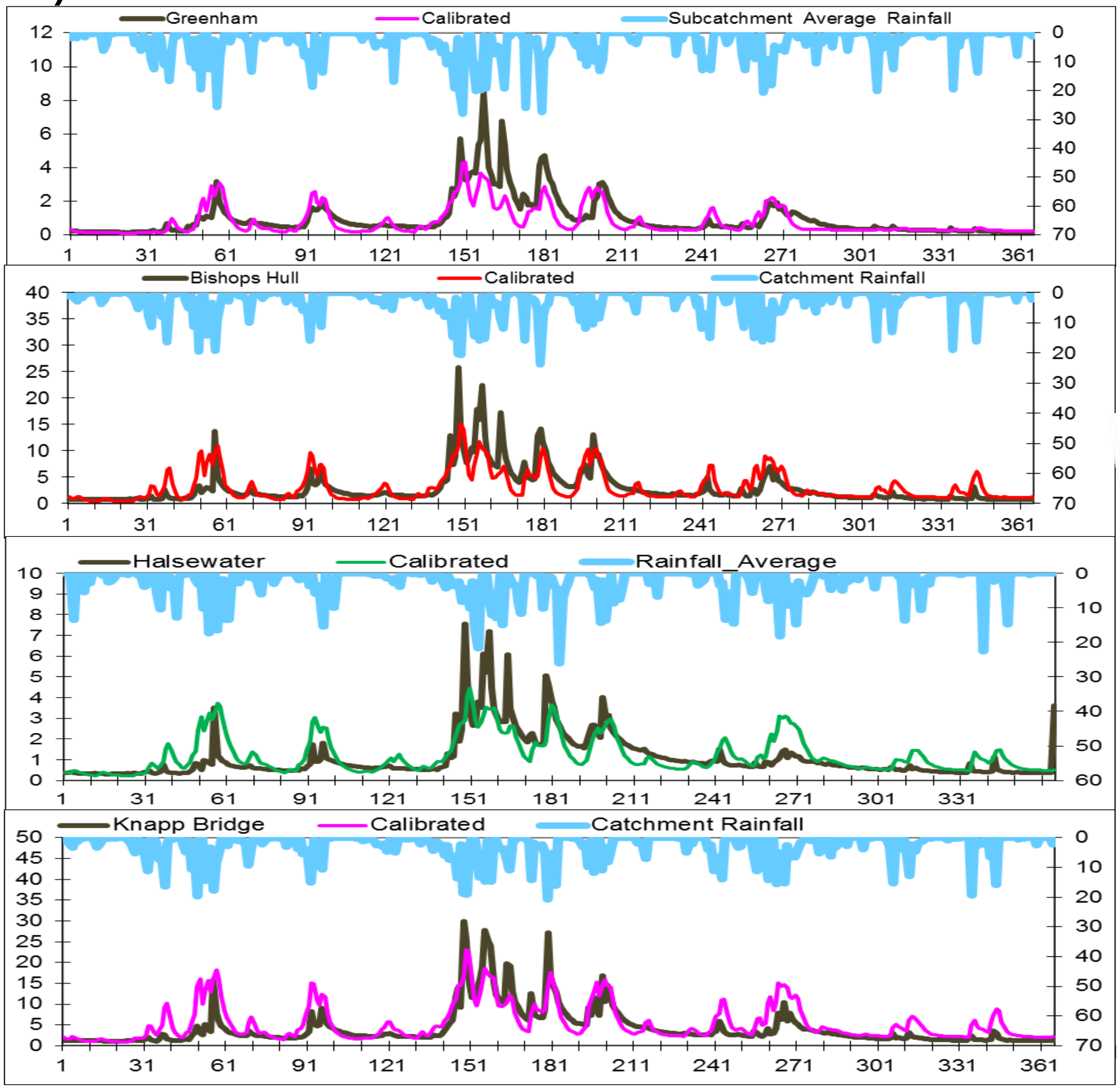
(m³/s)

UP

M/N

M/S

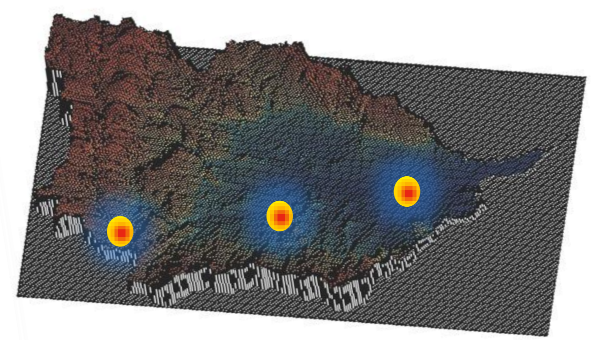
DN



(mm)

(1 Sept. 2001 ~ 31 Aug. 2002)

	RMSE	Correlation	Nash Sutcliffe
Greenham	0.73	0.80	0.60
Bishops Hull	2.50	0.71	0.51
Halsewater	0.80	0.69	0.44
Knapp Bridge	3.30	0.76	0.48



Validation Results

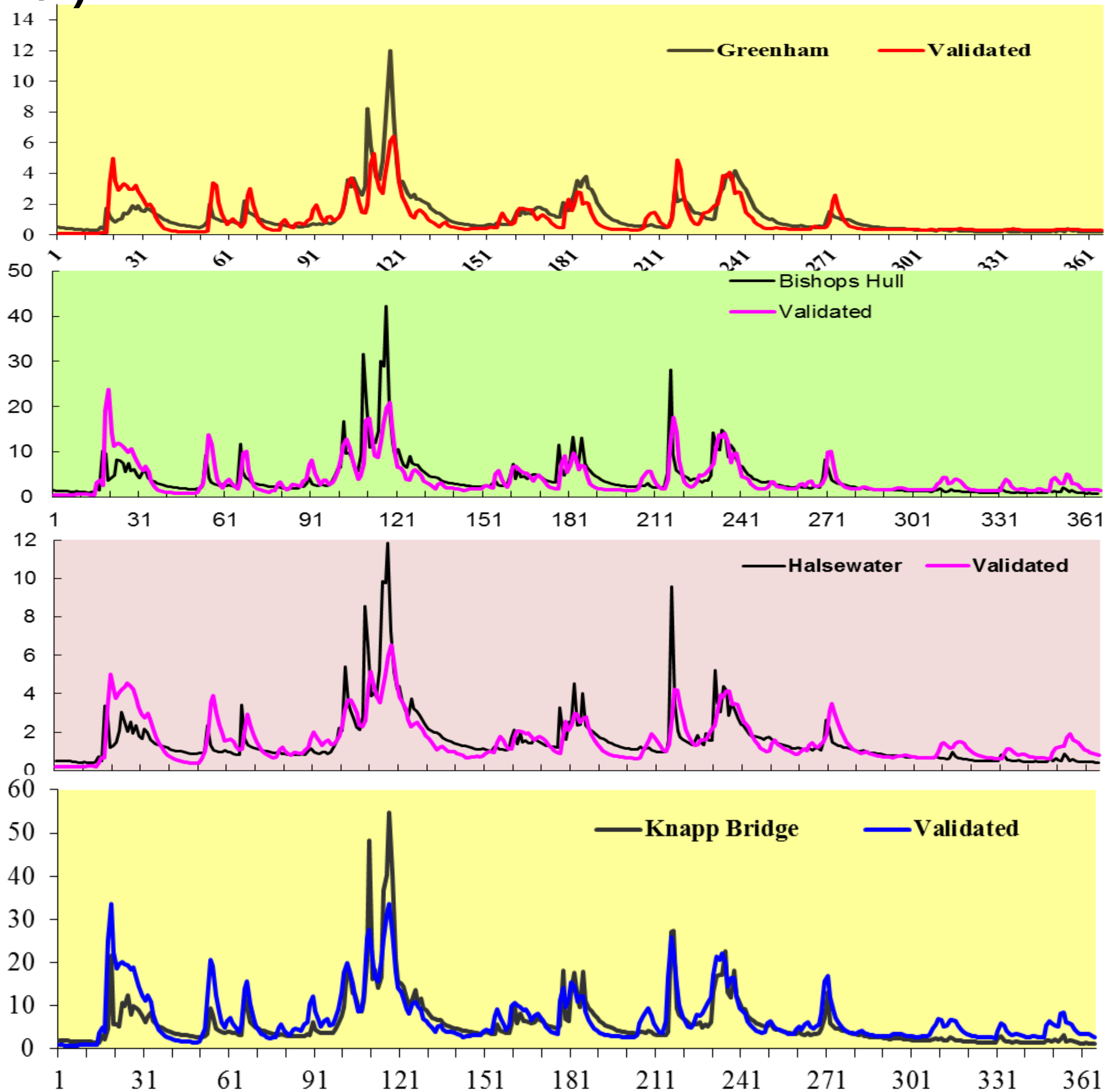
(m³/s)

UP

M/N

M/S

DN

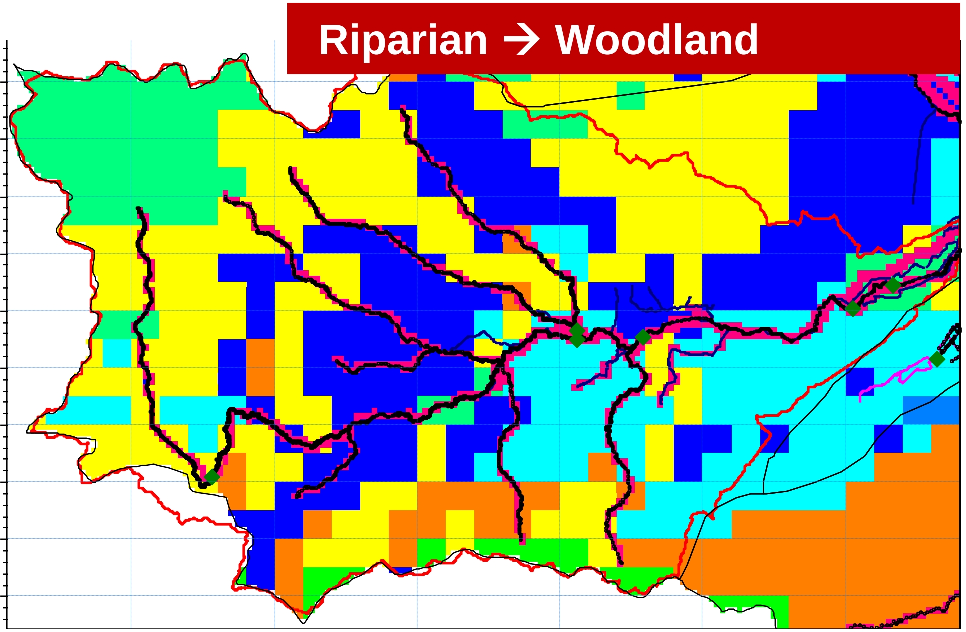


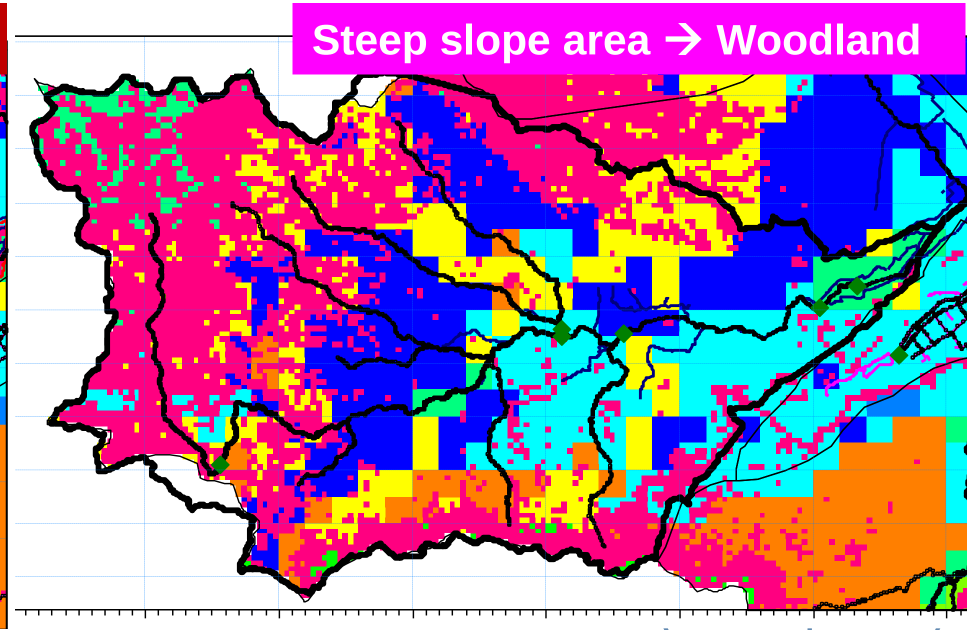
(1 Sept. 1999 ~ 31 Aug. 2000)

	RMSE	Correlation	Nash Sutcliffe
Greenham	0.88	0.76	0.57
Bishops Hull	3.50	0.66	0.42
Halsewater	1.06	0.67	0.44
Knapp Bridge	4.50	0.74	0.49

Scenarios: Land Use Changes

- **Scenarios are designed to examine the potential for the conversion of Riparian zone and Steep slope area to wood land.**
- **Assuming the conversion will reduce the rate of run-off by increasing infiltration and the potential water retention capacity of the soil.**





Impact of Land Use Changes

(m³/s)

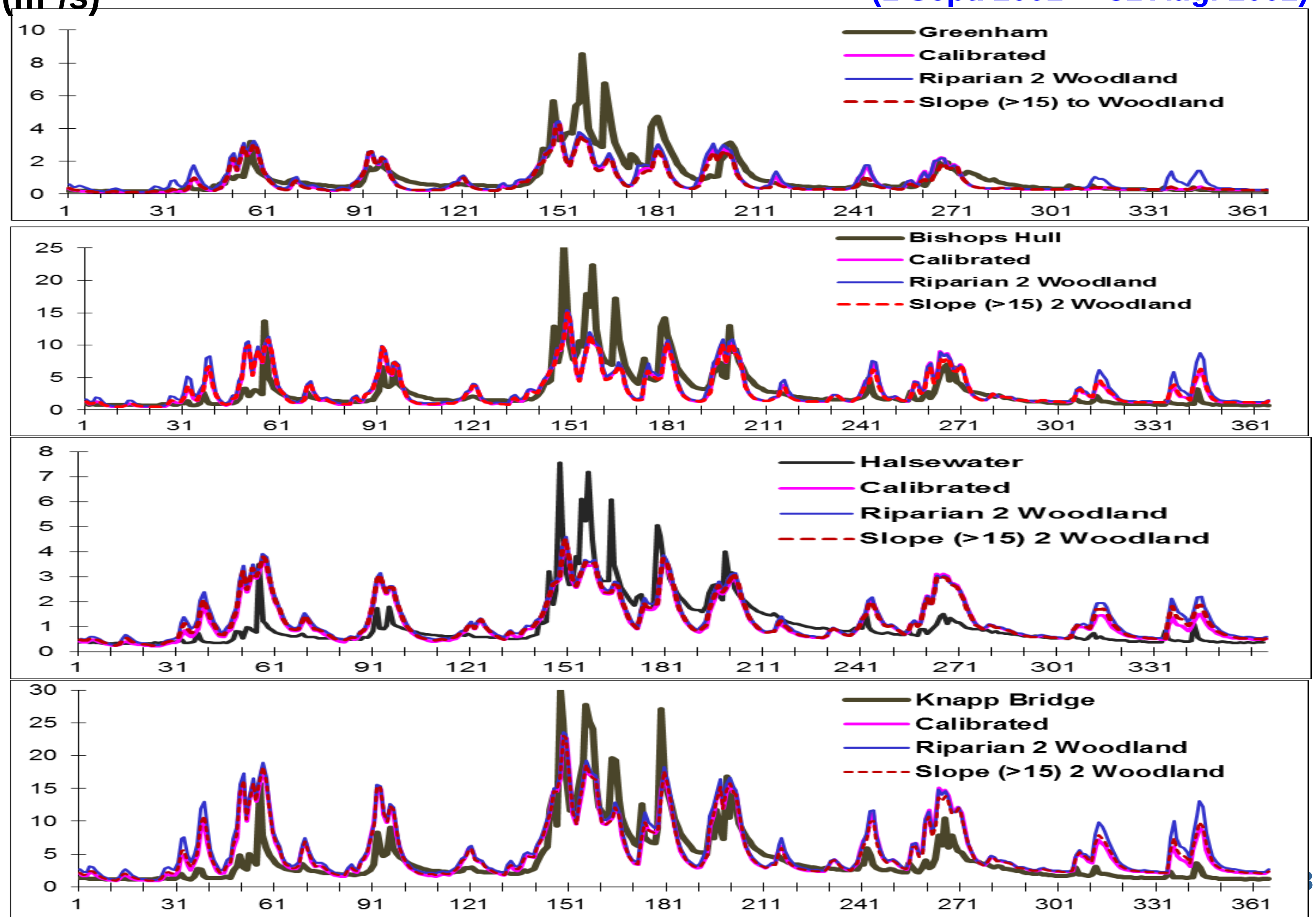
(1 Sept. 2001 ~ 31 Aug. 2002)

UP

M/N

M/S

DN

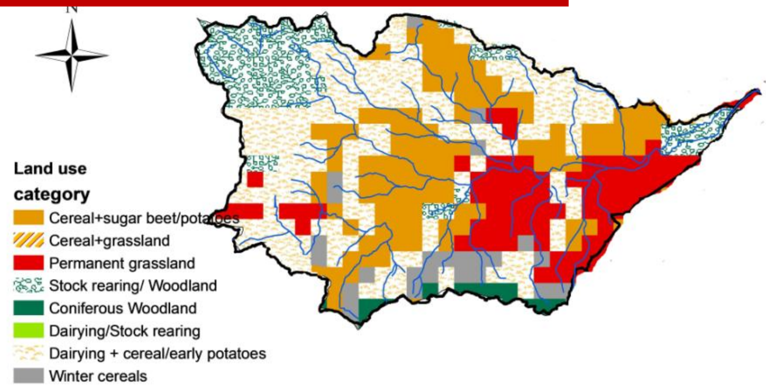


– 21 April 2011)

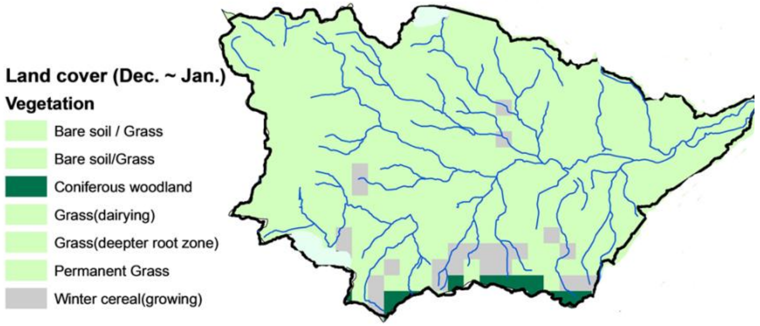
What else have to be considered ?

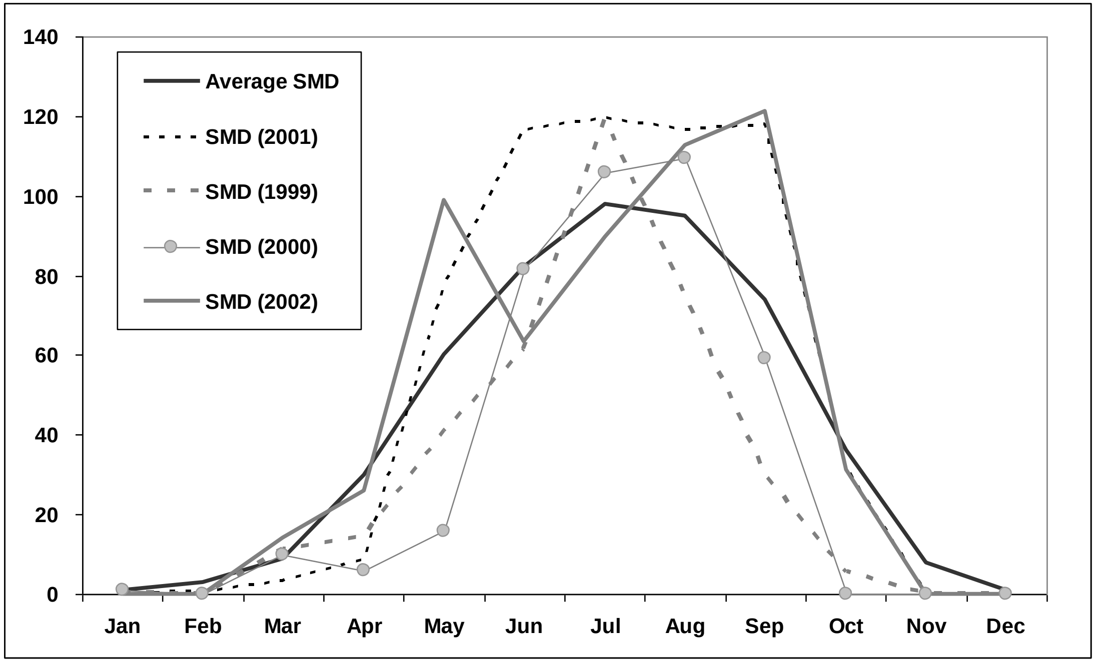
- **Changes on 5 – 20% of catchment area is big enough?**
- **Trees (Coniferous/Deciduous) can hold excess water when soil is fully saturated during wet season?**

Land use map considered



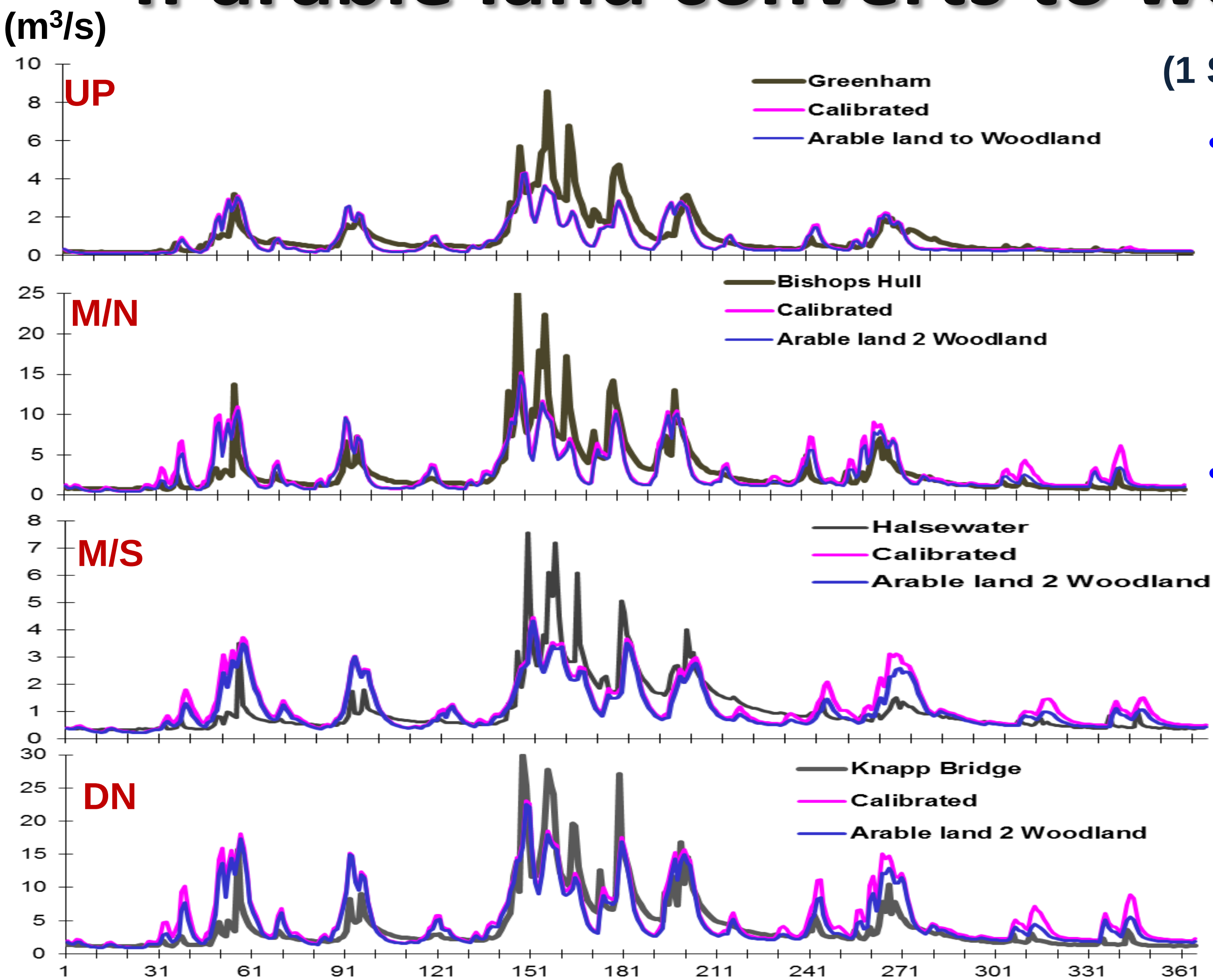
Surface (harvest ~ before seeding)





Average Soil Moisture Deficit (SMD) for 1961 ~ 2000 and years considered for calibration, validation and simulation.

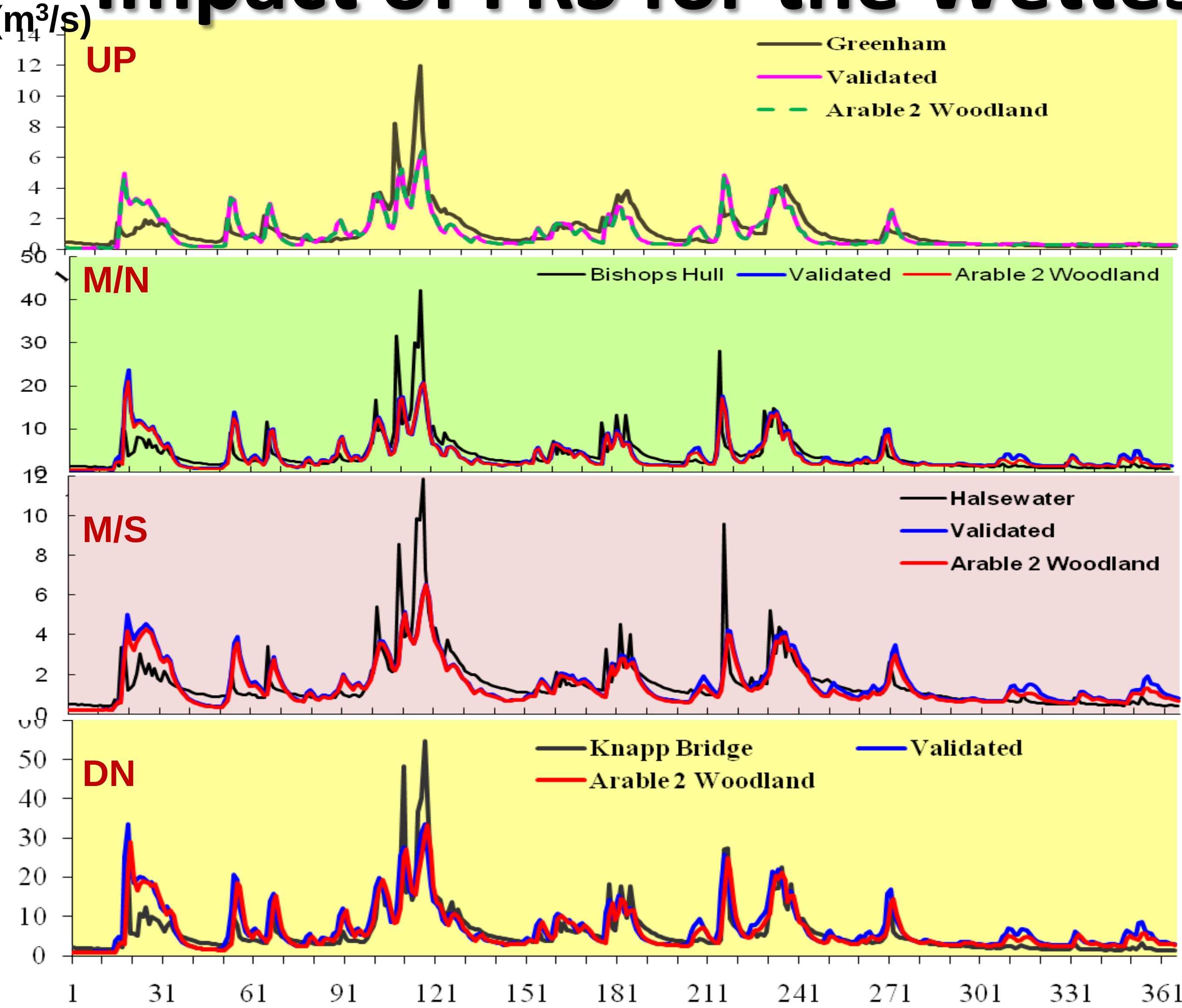
If arable land converts to woodland?



(1 Sept. 2001 ~ 31 Aug. 2002)

- **The conversion from arable landto wood land shows impact on reducing high flows between April and August.**
- **The changes are varied from the upper to down stream as the area is different and the impact are accumulated towards the river mouth.**

Impact of FRS for the Wettest Autumn



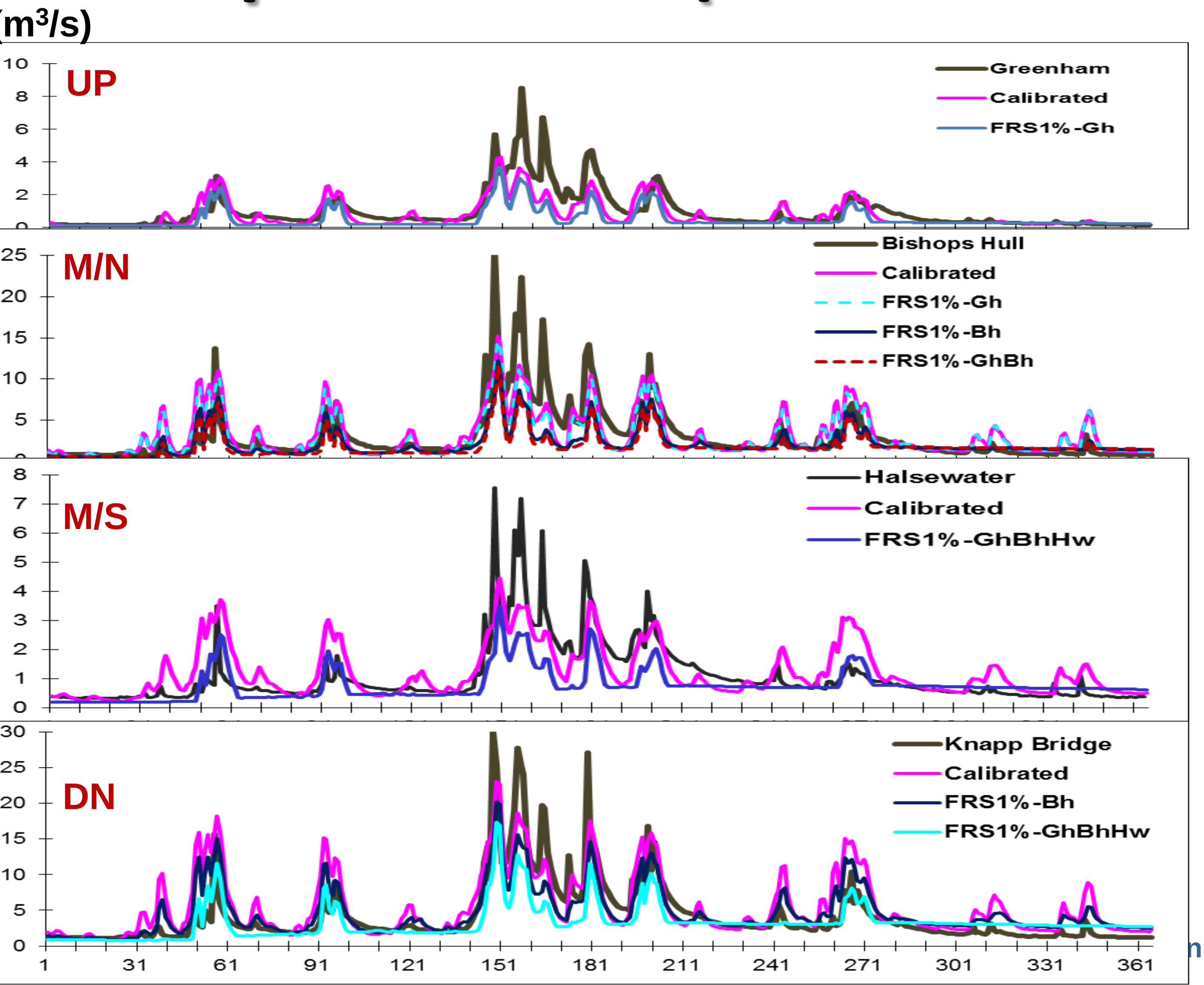
- **Sep 1999 – Aug 2000**
- **Not a noticeable change was observed on peak flow,**
- **However small changes are shown on water balance.**

Scenarios: Flood Retention Storage (FRS)

- **Designed to evaluate the potential and practicality of attenuating and delaying flood peaks by increasing the volume of floodwater stored temporarily on farmland on the floodplains in the upper and mid catchment.**
- **Assuming the storage would be installed covering from 0.5% ~ 3% of the surface area in each sub-catchment and capacity is presumed 25,000 cubic metres (The Reservoirs Act 1975).**

Courtesy: Bower Hinton farm storage from Parrett Catchment Project

Impact of FRS (1% of catchment area)



- <u>Sep 2001 – Aug 2002</u>
- **FRS in the Greenham catchment has rare impact on downstream**
- **Both Bishops Hull and Halsewater areas have about 30% decrease on peak flow**
- **Although this impact is decreased 20% of highest flow at Knapp Bridge**

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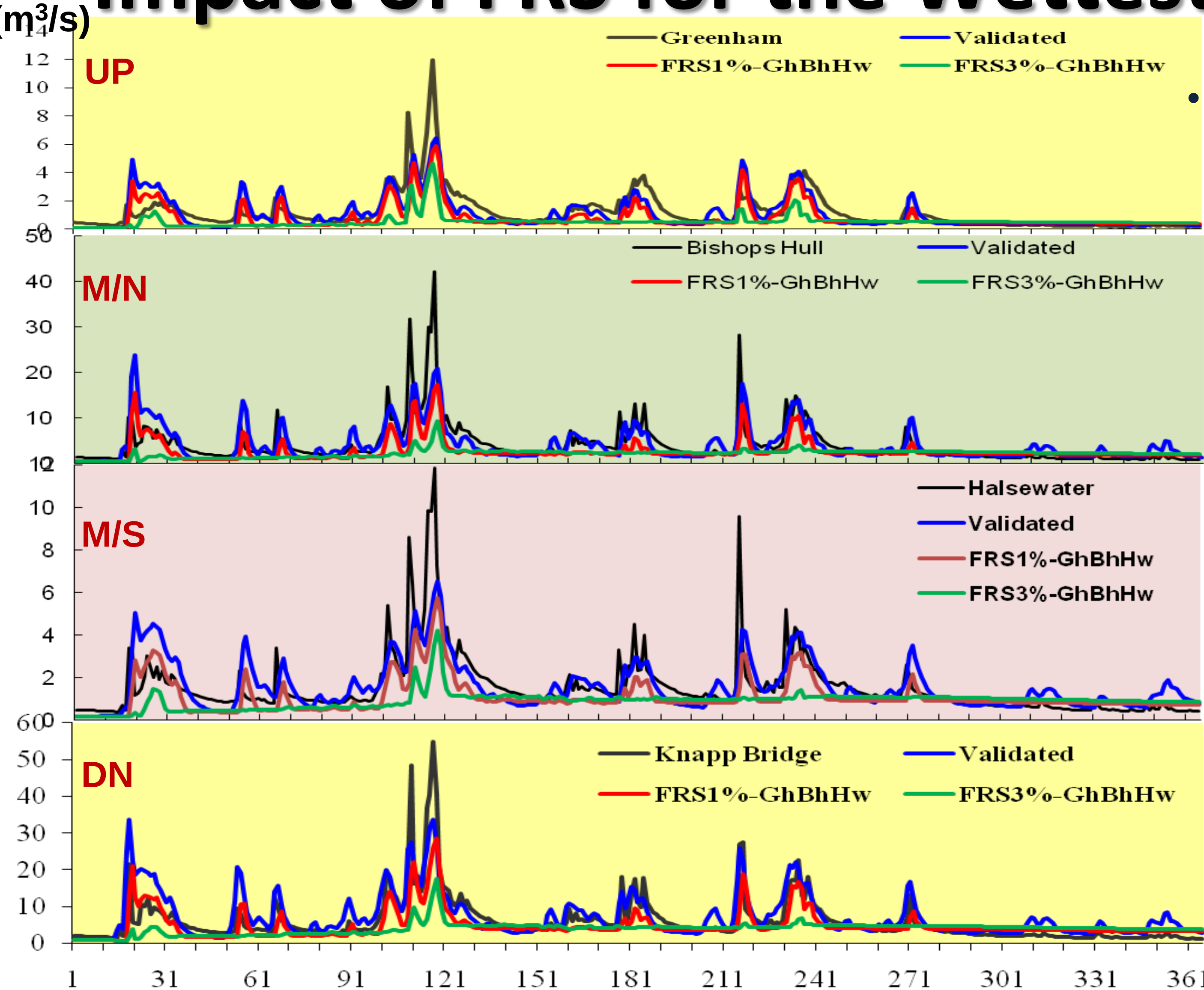
Impact of FRS for the Wettest Autumn



- <u>Sep 1999 – Aug 2000</u>
- **Assumed 1% and 3% of surface area would be FRS**
- **As flood intensity is 40 year period, FRS (1%) won't be not enough to reduce the risk,**
- **FRS (3%) shows dramatic impact on decreasing peak flow.**

Summary

- An integrated physically distributed model was built to explore the impact of land use changes with scenarios considering Crop Growing-Cycle and different size of Flood Retention Storages.
- Land use changes could be effective to reduce high flows when vegetations are fully grown, but it is hard to expect the same effect for wet season as it is after harvest, although the model structure has limitation on computing accurate ground water level.
- It does not mean that more changes can be observed at smaller scale, such as field/plot scale. The scale issue will continue to explore.
- Various range of FRS was considered in order to see how much water holding on upper and mid catchment could have impact on reducing flood risk.

Forward

- This study will continue to explore the impact of land use changes for the rest of the Parrett Catchment and a historical wetland as it is initiated at large catchment scale.
- Particularly seeking alternative of the lack of rainfall measurement is going on using global data – ECMWF ERA Interim data – using WRF (Weather and Research Forecast) model in order to improve model accuracy.
- Climate change impact will be simulated and Uncertainties raised through the work will be explored.
- The achievement will contribute for the better understand of catchment management and CFMPs (Catchment Flood Management Practices)

Acknowledgement

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Thank You!

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